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STRUCTURAL LINEAMENTS
IN THE SOUTHERN SIERRA NEVADA, CALIFORNIA

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STRUCTURAL LINEAMENTS IN THE SOUTHERN SIERRA NEVADA, CALIFORNIA

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ABSTRACT

Several lineaments observed in ERTS-1 MSS imagery over the southern Sierra Nevada of California have been studied in the field in an attempt to explain their geologic origins and significance. The lineaments are expressed topographically as alignments of linear valleys, elongate ridges, breaks in slope or combinations of these. The lineaments are typically less than 1 km wide, and several can be traced in the ERTS-1 imagery for over 30 km. Natural outcrop exposures along them are characteristically poor.

Two lineaments were found to align with foliated metamorphic roof pendants and screens within granitic country rocks. Along other lineaments, the most consistent correlations were found to be alignments of diabase dikes of Cretaceous age, and younger cataclastic shear zones and minor faults. Deep roadcut exposures in several key areas suggest that dikes and shear zones have controlled in-place weathering and erosion along the lineament trends. No evidence was found for hydrothermal alteration or Recent faulting.

The location of several Pliocene and Pleistocene volcanic centers at or near lineament intersections suggests that the lineaments may represent zones of crustal weakness which have provided conduits for rising magma.

Introduction:

ERTS-1 MSS imagery over the southern Sierra Nevada Range of eastern California has revealed a pattern of straight, narrow lineaments, some of which can be traced in the imagery for over 30 kilometers. Most of these features have not been mapped previously. Geologic reconnaissance along several of the lineaments was conducted by the authors in order to identify their geologic origins and significance.

The area of study is located on the Boreal Plateau (Webb, 1946) in parts of Tulare and Inyo Counties (Index Map, figure 2). Topographic relief on this portion of the plateau is moderate, with elevations ranging from 2,000 to 3,000 meters. Vegetation cover is moderate to extensive. Meadows and meandering stream valleys support lush growth

of grass, and the higher elevations are covered by chaparell and stands of pine, fir, and aspen trees.

The dominant rock types in the study area are plutonic, ranging in composition from quartz diorite to granite. In some areas, dike swarms are abundant. These dikes are predominately fine-grained diabase and porphyritic gabbro, although rhyolites, aplites and pegmatites are found locally (Miller and Webb, 1940).

Large, irregular roof pendants of foliated metamorphic rock are mapped in many parts of the study area (Miller and Webb, 1940; Matthews and Burnett, 1966; Smith, 1965). Small pendants and screens of similar metamorphic rock are also widespread, although most of these do not appear at the scale of existing geologic maps.

ERTS-1 MSS Imagery:

Figure 1 shows an enlarged portion of ERTS-1 MSS frame #1162-18011, Band 5. A corresponding topographic map showing the positions of lineaments interpreted from the imagery is illustrated in Figure 2.

ERTS-1 scenes recorded over a 12-month period were studied in this investigation. Seasonal variation of sun angle and snow cover were found to change the expression of some lineaments; however, each of the lineaments shown in Figures 1 and 2 were visible throughout the seasonal span. Seasonal variation of vegetation was not observed to affect expression of the lineaments.

ERTS-1 MSS frames having low to moderate cloud coverage are as follows:

15 September 1972	Frame #1054-18003
21 October 1972	1090-18010
14 December 1972	1144-18012
1 January 1973	1162-18011
12 June 1973	1324-18011
30 June 1973	1324-18010

The ERTS-1 MSS imagery was studied with a Spectral Data Corporation model 61 additive color viewer to determine optimum band/filter combinations and color balance for enhancement of geologic detail. High resolution color composites (MacGalliard and Liggett, 1973) were produced at the scale of 1:500,000 for detailed analysis and interpretation. The positions of key structural anomalies observed in this imagery were transferred to 1:250,000 and 1:62,500 scale topographic quadrangles to facilitate field reconnaissance.

Lineaments:

The lineaments are expressed topographically as alignments of linear valleys, elongate ridges, breaks in slope or combinations of these. Several lineaments can be traced in

the ERTS-1 imagery for over 30 km, and are typically less than 1 km wide.

The dominant trend of the lineaments in the area is slightly east of north. This system is crossed by less numerous lineaments which strike toward the northeast as shown in Figures 1 and 2. The Kern Canyon Fault Zone (Webb, 1955) is the only major structural feature mapped in the area of study. Only small portions of three other lineaments have been previously mapped as faults (see Smith, 1965; Matthews and Burnett, 1966).

In a structural reconnaissance of the southern Sierra Nevada, Mayo (1947) recognized several pervasive structural patterns which he attributed to such phenomena as igneous "flow structure" and post batholithic "joint swarms" and "fissures". The orientation of these features closely parallel the three directional trends apparent in Figures 1 and 2.

During field reconnaissance, two lineaments were found to align with the foliation or compositional layering of metamorphic rocks. Lineament Y-Y shown in Figure 2 is located within a large roof pendant in which the foliation and layering parallels the west-northwest strike of the lineament. Similar exposures along lineament X-X reveal a thin, elongate screen of metamorphic rock in which the foliation and compositional layering align with the lineament. No faulting was recognized along the traces of these lineaments, and their topographic expression as elongate ridges and valleys appears to have been controlled by preferential weathering and erosion of the foliated rock.

The north-south striking lineaments are found to have characteristically vague expression in natural outcrop exposures. Within the areas studied, these lineaments cross varied plutonic country rocks and are confined to valleys or breaks in slope. Sparse outcroppings are found even where lineaments cross topographic saddles.

For these reasons, close study was made of available exposures. Where feasible, measurements were made of such features as igneous foliation, cataclastic foliation, metamorphic foliation or compositional layering, dikes, shear zones, slickensides, epidotized joints, and the dominant trends of these features inferred within each outcrop area in the field.

Dikes:

The dikes indicated in Figure 3 are hornblende diabase, similar in composition and texture throughout the study area. The dikes generally range in width from 0.5 to 5.0 m and are nearly vertical in dip. In areas of good exposure along lineaments, the dikes are spaced at intervals of less than 2 m. Dikes within a swarm typically strike within 10^{o} of each other, although frequently two trends intersecting at a high angle are found within a local area. This bimodal pattern is apparent in the orientation diagrams of Figure 3.

The mafic dikes cut both plutonic and metamorphic country rocks, and are themselves cut only rarely by rhyolite dikes. A K-Ar age date from a north 20^{o} east-striking dike at Station C in Figure 3 (specimen 73L31) yielded an apparent mid-Cretaceous age of 105 $\pm$ 5 m.y.

Structures:

Structural features included in the trend diagrams of Figure 3 include cataclastic foliation, slickensided joints and faults. These structures cut across the diabase dikes and are, therefore, younger. Epidotized joints or fractures lacking evidence of movement were not included in the diagrams.

Shears cutting the plutonic country rocks typically appear as planes or zones 1 to 2 cm wide in which the granitic texture of the host is cataclastically foliated. Where well exposed, these planes are found to be subparallel in strike, nearly vertical in dip, and spaced at intervals of a few centimeters to about 1 m.

Within the shear zones, movement is indicated by slickensides, many with sub-horizontal plunges. Slickensides are best preserved on joints or shears which have been epidotized. As shown in the trend diagrams of Figure 3, the strike of shears, joints and fault planes, like the diabase dikes is frequently bimodal.

Discussion:

The continuity of dike swarms and cataclastic shearing along the entire lengths of the lineaments is not documented because of the characteristically poor exposures. However, in several key areas where roadcuts have exposed the deeply weathered granitic rocks along lineaments, slickensided joints and diabase dikes are apparent in far greater abundance than in the adjacent natural outcrop exposures. Examples of this are visible in roadcuts at Station F shown in Figure 3. This selective exposure is believed to be the result of lithologic and structural control of in-place weathering and erosion.

The glassy groundmass, mafic mineralogy and closely spaced jointing of the diabase dikes make them prone to rapid chemical and mechanical weathering. As a result, the positions of former dikes are frequently expressed in outcrops as linear debris-filled depressions. Similar expression is observed in the selective weathering of granitic rocks along shear zones or closely spaced joints, where large surface areas are exposed to chemical and mechanical weathering processes (Thornbury, 1954). These processes favor preservation of natural outcrop exposures which have the fewest shear zones, faults or dikes.

At the reconnaissance scale of this study, no direct evidence was found supporting major displacement of lithologic units across the lineaments. Although some faulting and shearing may be Recent in age, the topographic expression of the lineaments is due to selective weathering and erosion, and not primary topographic displacement.

Mayo (1947) suggested possible structural control of several late Tertiary and Quaternary volcanic centers in the area of this report. These volcanic centers appear to be located at or near the intersection of the lineament systems shown in Figure 2. However, little field evidence was found to confirm structural control. Radiometric ages from a basalt field along the Kern River south of Angora Mountain indicate a late Pliocene age (Matthews and Burnett, 1966). Olivine basalt cinder cones and flows along Golden Trout Creek east of the Kern River are believed to be of Quaternary or Recent age (Webb, 1950).

Monache and Templeton Mountains are large volcanic domes composed of aphanitic latite (Webb, 1950) and considered to be of probable late Tertiary or Quaternary age. Possible structural control of the Monache Mountain dome is suggested by the existence of numerous felsic dikes intruded along fractures adjacent to older diabase dikes in exposures surrounding Monache Meadows.

Conclusions:

At regional scale, the lineament systems discussed in this report, appear to control much of the topography in the southern Sierra Nevada. The origin of these features is uncertain. Their apparent correlations with faulting, jointing, dike swarms and volcanic centers suggest that they may represent steeply-dipping zones of crustal weakness within the Sierra Nevada Batholith. These zones appear to have existed at the time of intrusion of the mid Cretaceous diabase dikes, and may have been reactivated during Tertiary and Quaternary orogenic and volcanic events.

It is hoped that future, detailed studies will help determine the age, precise origins and geological implications of these features.

Although the lineaments are perhaps the largest post-batholithic structural features in the southern Sierra Nevada, they have not been generally recognized on the basis of previous geologic mapping. The ERTS-1 MSS data has proved to be an effective tool for recognition of these large-scale structural anomalies, and for guiding reconnaissance in the field.

Figure 1: Enlarged portion of ERTS-1 MSS frame #1162-18011 Band 5 over the southern Sierra Nevada, California. A corresponding topographic map is shown in Figure 2.

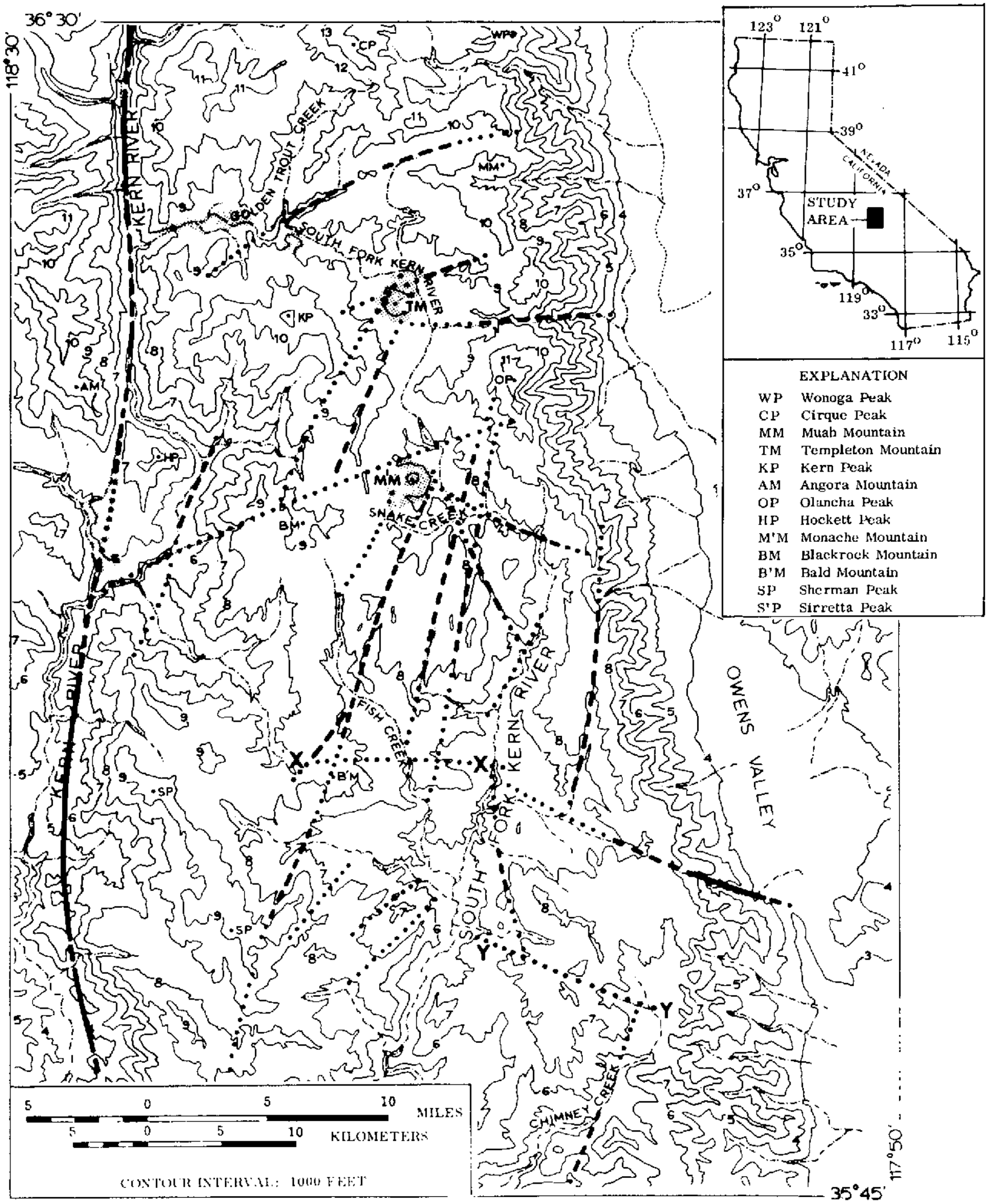

Figure 2: Interpretation of major lineament systems visible in the ERTS-1 image of Figure 1. Location names follow the code shown at right. Topography is from the AMS Fresno and Bakersfield $1^{o} \times 2^{o}$ quadrangles. See text for more detailed discussion.

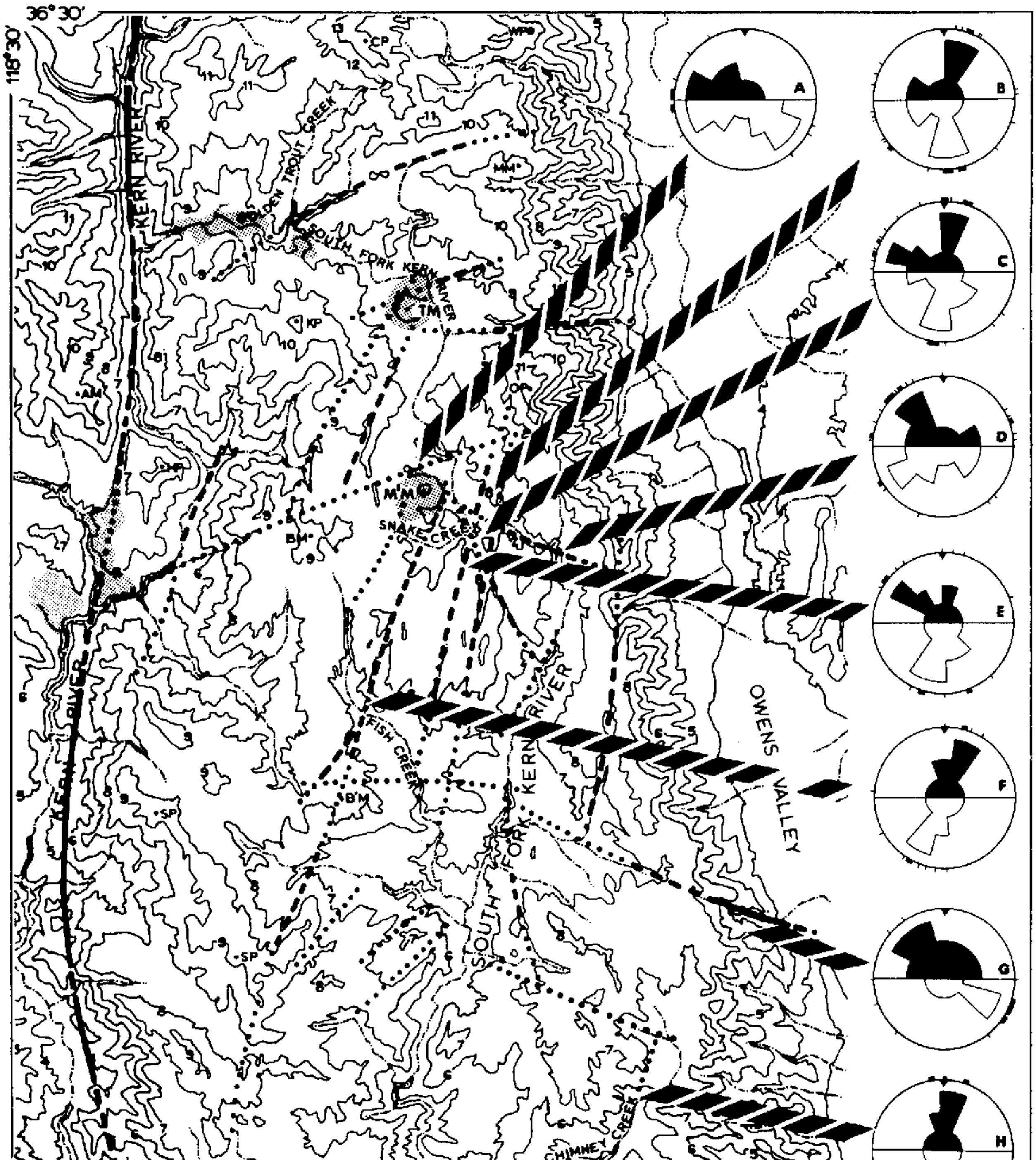

Figure 3: Orientation diagrams for steeply dipping diabase dikes (upper half circle) and faults, slickensided joints and cataclastic foliation (lower half circle). Tick marks on the circumference indicate measured strikes. The generalized rose diagrams illustrate inferred patterns; the outer radius contains over 50% of local strikes, middle radius approximately 30%, and short radius less than 20%.

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